EFFECT OF BLEACHING AGENTS AND WHITENING TOOTH PASTES ON COLOR STABILITY AND MICROHARDNESS OF RESTORATIVE MATERIALS

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ABSTRACT

The purpose of this study was to compare the effect of in-office and home bleaching gels and of whitening tooth pastes, on the color stability and microhardness of two resin composites and one resin-modified glass-ionomer cement. Thirty-five disk specimens were fabricated from each of the restorative materials (Z250, Esthet-X and Fuji II). Specimens of each material were divided randomly into seven groups of five specimens. The first and second groups were treated with Opalescence Xtra in-office bleaching gel and with Nite-White home bleaching gel, respectively following the manufacturers' instructions. The third group was treated with Signal 2 cavity fighter regular tooth paste. The fourth, fifth and sixth groups were treated with whitening tooth pastes (Crest Extra Whitening, Advance White, and Aquafresh Whitening). The seventh group was stored in normal saline to serve as a control. The color and Vickers surface microhardness of each specimen were recorded before and after treatments. Results indicated that, although the microhardness of Z250 resin composite was significantly reduced by Opalescence Xtra bleaching gel, its color stability was not affected by any of the tested products. However, significant color change and reduction in microhardness of Esthet-X resin composite were observed after treatment with Opalescence Xtra bleaching gel. Fuji II LC showed significant color change and reduction in microhardness with both of the bleaching gels and significant color change with all tooth pastes. However, the microhardness of all three restorative materials was increased significantly by all tooth pastes.

Key words: *Bleaching Agents, Whitening Tooth Pastes, Microhardness, Color, Restorative Materials.*

INTRODUCTION

The requirement for esthetic dental benefits is high-lighted by the rapid growth of tooth whitening products. Home vital tooth bleaching has attracted the interest of people due to high success rates, ease of use and media publicity.[1,2] The procedure uses products with low concentrations of hydrogen peroxide (3-7%) and carbamide peroxide (10-22%)[3,4] The in-office bleaching products contain a strong oxidizing agent (30-37% hydrogen peroxide) used under the dentist's control.[5] The influence of various concentrations of bleaching agents on the physical properties, surface morphology and color change of tooth structure and different restorative materials has been investigated in several in vitro studies, simulating the clinical situations as closely as possible.6-11 Some of these studies showed that 35% hydrogen peroxide and 10-16% carbamide peroxide alter enamel surface morphology, cause surface deterioration of existing restorations and induce bacterial adhesion.[6,7] However, other investigations revealed no significant changes in enamel and the physical properties of existing restorations from bleaching agents.[8,9] Some studies even reported an increase in enamel and resin composite surface hardness following bleaching.[10,11]

In addition to regular tooth pastes, a considerable number of whitening tooth pastes has been developed.[12] Manufacturers claim that whitening tooth pastes are formulated to remove extrinsic dental stain rather than to change the natural tooth color through a

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bleaching action.[13] These whitening tooth pastes contain abrasive particles such as natural calcium carbonate and silica microgranules.[14] Some formulations of whitening tooth pastes may contain small percentages of hydrogen peroxide and carbamide peroxide.[15] Baking soda also has been introduced in some formulations of whitening tooth pastes to provide anti-halitosis and anti-bacterial effects,[16] but concern has been raised regarding the high abrasive action of baking soda.[17] Little is known about the effect of these whitening tooth pastes on soft tissues, tooth structure and the physical properties of restorative materials.

The appearance of natural teeth and restorative materials varies according to their color and translucency.[18] The esthetic properties of an existing restoration are important factors that affect clinical success. The initial color match of a light-polymerized restoration may be excellent, but long-term color changes can occur because of surface and marginal staining. Drastic color changes to existing restorations may compromise esthetics. Therefore, it is important to understand the effects of whitening products, including the daily usage of whitening tooth pastes, on the color of restorative materials.

The purpose of this study was to determine the color and surface microhardness changes that may occur in two light-polymerized resin composites and one resin-modified glass-ionomer cement from using various whitening tooth pastes, and home and in-office bleaching agents. The first hypothesis tested assumed that only the bleaching agents would change the color of all restorative materials. The second hypothesis tested was that the bleaching agents would reduce the surface hardness of all restorative materials, while the whitening tooth pastes would increase their surface hardness.

MATERIALS AND METHODS

Shade A2 was selected from three restorative materials, Z250, Esthet-X, and Fuji II LC. Details of the restorative materials are listed in Table 1. The materials were injected into Teflon molds (10 mm diameter and 1.5 mm high), covered with Mylar strips, and pressed between glass plates. After 10 s light curing with a Prismetics unit (LD Caulk Dentsply) at 450 mW/cm2 light output, the top glass plates were removed to position the wand tip closer to the specimens. Each specimen was then polymerized for another 30 s. Thirty-five specimens from each material were fabricated and stored in darkness at room temperature for 24 h to allow optimum conversion. Specimens from each material were divided randomly into seven groups (n=5), using a computer program. One regular tooth paste, three whitening tooth pastes and two bleaching gels were selected as the treatment products (Table 2). The control group was stored in normal saline. Baseline color measurement of each specimen was recorded before treatment using a spectrophotometer (PSD 1000, Ocean Optics, FL, USA). Surface microhardness measurements also were recorded before treatment using a microhardness tester with a Vickers diamond indenter (Micromet 21000, Beuhler Ltd, IL, USA). A load of 300 g was applied to the surface of each specimen for 12 s, then the indentation depth number was taken from the dial gauge. Three indentations, which were equally placed over a circle and not closer than 1 mm to the adjacent indentations or to the margin of the specimens, were recorded from the surface of each specimen.

Material	Manufacturer	Composition
Z250 (Hybrid resin composite)	3M ESPE Dental Products, St. Paul, MN, USA	Bis-GMA, UDMA, Bis-EMAzirconia/silica filler (60% by vol) particle size 0.01-3.5 µm
Esthet-X (Hybrid with micro- matrix resin composite)	DENTSPLY, Hamm Moor Lane, Addlestone, UK	Bis-GMA, Bis-EMA, TEGDMA, barium fluoro-aluminoboro-silicate (60% by vol) particle size <1.0 µm, nano-sized silicon dioxide,
Fuji II LC (Resin-modified glass-ionomer cement)	GC International Corp., Tokyo, Japan	Co-polymer of maleic and acrylic acids, 2-HEMA, waterfluoroaluminosilicate glass

TABLE 1: RESTORATIVE MATERIALS AND COMPOSITION.

Whitening products	Manufacturer	Composition
Opalescence Xtra Boost (in-office bleaching)	Ultradent Products Inc., South Jordan, Utah, USA.	37% chemically activated hydrogen peroxide.
Nite-White (home bleaching)	Discus Dental, Culver city, CA, USA	10% carbamide peroxide
Signal 2 cavity fighter	Binzagar Lever Ltd, Jeddah, Saudi Arabia	calcium glycerophosphate, calcium carbonate, carbonate, sorbitol, water, silica, sodium lauryl sulfate, sodium monofluorophosphate, mix of flavors, cellulose gum, trisodium phosphate, sodium saccharin, formaldehyde, Cl 12490
Crest Extra Whitening	Procter & Gamble, Cincinnati, OH, USA	water, hydrated silica, sorbitol, glycerin, PEG-6, sodium lauryl sulfate, tetrapotassium, sodium bicarbonate, citric acid, pyrophosphate, aroma, carbomer, carnauba, cellulose gum, limonene, sodium fluoride, sodium saccharin, triclosan, xanthan gum, Cl 74160, Cl 77891
Advance White	Arm & Hammer, Church & Dwight Co. Inc., Princeton, NJ, USA	sodium fluoride, sorbitol, sodium bicarbonate, hydrogen peroxide, glycerin, silica, water, sodium saccharin, mix of flavors, cellulose gum, sodium lauryl sulfate, titanium dioxide,
Aquafresh Whitening	Glaxo Simith Kline, Brentford, UK	hydrated silica, water, sorbitol, glycerin, pentasodium, tri-phosphate, PEG-6, sodium lauryl sulfate, flavor, titanium dioxide, xanthan gum, sodium hydroxide, sodium saccharin, sodium fluoride, Cl 73360, Cl 74160

TABLE 2: TREATMENTS PRODUCTS AND COMPOSITION.

TABLE 3: MEANS AND STANDARD DEVIATIONS FOR COLOR CHANGE (ΔE) AFTER TREATMENT WITH THE DIFFERENT WHITENING PRODUCTS.

Treatment (n: 5 each)	Z250	Esthet-X	Fuji II LC
Opalescence Xtra	1.9 (0.5)a	7.9 (0.5)*b	9.6 (1.5)*
Nite-White	0.6 (0.4)a	2.1 (1.8)a	6.2 (1.9)*ab
Signal 2 cavity fighter	1.2 (0.4)a	1.3 (0.4)a	3.5 (0.8)*
Crest Extra Whitening	1.6 (1.2)a	5.1 (0.9)*b	5.0 (1.5)*
Advance White	1.1 (0.7)a	1.8 (0.4)a	5.8 (1.0)*a
Aquafresh Whitening	1.2 (0.2)a	1.3 (0.3)a	6.9 (0.9)*b
Saline (control)	0.9 (0.6)a	1.0 (0.8)a	0.9 (0.6)

* Means are significantly different from control (P<0.05)
Means with the same letter are not significantly different from one another

After measuring the baseline color and microhardness of the specimens, the treatments of each group were performed. For the home bleaching group (Nite-White), specimens were immersed for 4 h daily in fresh bleaching gel, following the manufacturer's directions. The specimens were rinsed with deionized water after each treatment, and then stored in deionized water between treatments. The home bleaching treatments were continued for one month. For the in-office bleaching group (Opalescence Xtra Boost), specimens were immersed in the bleaching gel for 15 min, following the manufacturer's directions. After agitation of the gel every 5 min, it was removed by suction tip and the specimens rinsed with

Source	Type III Sum of Squares	df	Mean Square	F	P-value
Whitening materials	4509.78	6	751.63	212.11	.000
Restorative material	1522.67	2	761.34	214.85	.000
Whitening materials* Restorative material	1517.39	12	126.45	35.68	.000

TABLE 4: TWO-WAY ANOVA OF COLOR CHANGE AFTER TREATMENT WITH THE DIFFERENT WHITENING PRODUCTS.

TABLE 5: MEAN VICKERS HARDNESS VALUES AND THE STANDARD DEVIATIONS (SD) FOR THE THREE RESTORATIVE MATERIALS BEFORE AND AFTER TREATMENT WITH THE DIFFERENT WHITENING PRODUCTS.

Whitening product	Z250		Esthet-X		Fuji II	
	Before	After	Before	After	Before	After
Opalescence Xtra Xtra	87.7 (2.2)^{a}	68.7* (3.3)	62.4 (4.0)^{c}	43.9* (3.0)	54.7 (1.2)^{e}	41.7* (3.6)
Nite-White	89.6 (2.3)^{a}	87.1 (2.2)^{a}	61.9 (3.3)^{c}	62.9 (2.6)^{c}	56.1 (1.5)^{e}	42.2* (2.9)
Signal 2 cavity fighter	86.6 (2.5)^{a}	105.8* (3.1)^{b}	62.9 (3.5)^{c}	75.8* (4.4)^{d}	55.9 (2.3)^{e}	67.0* (3.1)
Crest Extra Whitening	88.0 (2.3)^{a}	102.2* (2.2)^{b}	62.7 (2.6)^{c}	88.0* (3.2)	56.5 (3.0)^{e}	78.0* (2.3)
Advance White	87.4 (2.3)^{a}	100.5* (2.5)^{b}	62.7 (4.4)^{c}	73.8* (1.5)^{d}	56.5 (2.8)^{e}	66.3* (1.1)
Aquafresh Whitening	88.5 (2.1)^{a}	104.0* (3.7)^{b}	61.9 (2.7)^{c}	74.4* (3.7)	55.7 (1.4)^{e}	69.7* (2.1)
Saline (control)	87.2 (3.2)^{a}	89.6 (2.3)^{a}	61.9 (2.9)^{d}	63.3 (1.2)^{d}	56.3 (2.6)^{e}	57.2 (2.4)^{e}

* Means are significantly different from control ($P<0.05$). Means with the same letter are not significantly different from one another

Source	Type III Sum of Squares	df	Mean Square	F	P-value
Whitening materials	12421.92	6	2070.32	60.43	.000
Restorative material	393.09	2	196.54	5.74	.000
Whitening materials* Restorative material	2358.58	12	196.55	5.74	.000

TABLE 6: TWO-WAY ANOVA OF VICKERS HARDNESS AFTER TREATMENT WITH THE DIFFERENT WHITENING PRODUCTS.

deionized water. Fresh gel was applied after 15 min for three times. The same procedure was repeated after one week, keeping the samples in deionized water between treatments. For the tooth pastes groups; the specimen surfaces in each group were brushed with an electric tooth brush (Colgate ActiBrush, Colgate Oral pharmaceuticals, 1 Colgate way, Canton, MA, USA) for 2 min twice daily, with a new brush tip for each tooth paste. The tooth brush was held perpendicular to the specimen surfaces without applying pressure, as described elsewhere.[19] The same procedure was repeated for 30 d. Following each treatment, the specimens were rinsed then stored in deionized water between treatments.

After finishing all treatments, the color and microhardness of the specimens were measured. Color change was measured according to the following formula used in previous studies.[20-22]

$$\Delta E^*=[(L^*_o-L^*_I)^2+(a^*_o-a^*_I)^2+(b^*_o-b^*_I)^2]^{1/2}$$

ΔE^* = color change, L^* = luminance reflectance, a^* = red-green color coordinate, b^* = yellow-blue color coordinate, O = baseline, and I = after treatment.

Three different intervals were used for distinguishing color differences. Values of $\Delta E^* < 1$ were regarded as not detectable by the human eye. Values of $\Delta E^* < 3.3$ were considered detectable by skilled operators, but clinically acceptable, while values of $\Delta E^* > 3.3$ were considered detectable also by non-skilled persons and, for that reason, were clinically not acceptable.[23-25]

Color change ΔE^* data and microhardness values were analyzed by two-way analysis of variance (ANOVA) and the post hoc Tukey's test. The probability for statistical significance was set at $\alpha = 0.05$.

RESULTS

Color

The mean and standard deviation values for color change (ΔE^*) of the specimens produced by each of the products used are summarized in Table 3.

Two-way ANOVA showed that both the restorative materials and whitening products were significant (Table 4). Significant interaction also was found between the restorative materials and the treatment products ($P<0.001$).

Z250 resin composite showed the greatest color stability among the materials. Though some color change was noticed with several of the treatment products, it was not clinically significant. The color of Esthet-X resin composite was affected significantly after treatment with Opalescence Xtra in-office bleaching gel ($P<0.001$) and Crest Extra Whitening tooth paste ($P<0.001$).

Fuji II LC was found to be the least resistance to color change. All of the tooth pastes and bleaching gels caused a significant color change for Fuji II, but Opalescence Xtra bleaching gel caused the most significant color change ($P<0.001$).

Microhardness

The microhardness results are shown in Table 5 and Figures 1-3. Two-way ANOVA (Table 6) indicated significant differences for the type of treatment product and restorative material ($P<0.001$). Significant interaction also was found between the restorative materials and the whitening products ($P<0.001$).

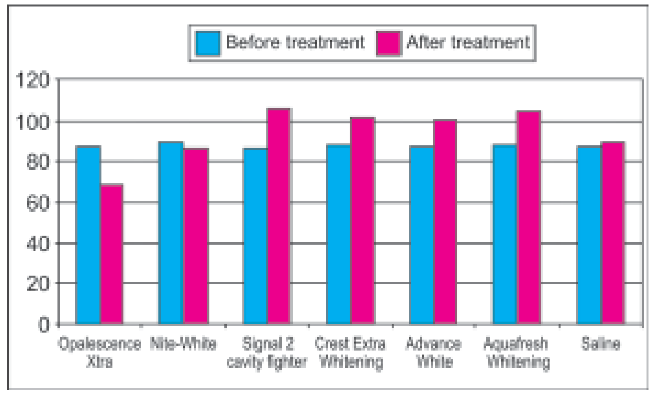

Fig. 1: Mean Vickers hardness values for Z250 resin composite before and after treatment with the different whitening products.

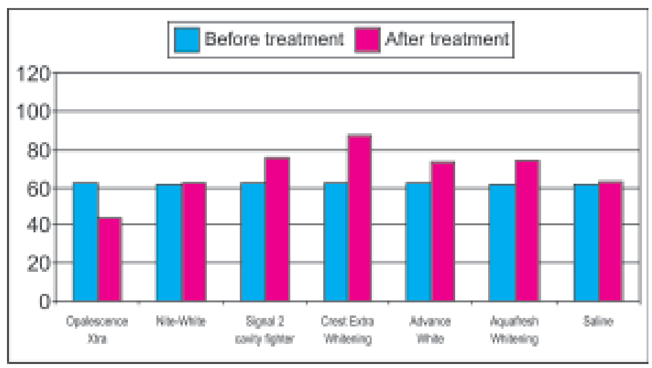

Fig. 2: Mean Vickers hardness values for Esthet-x resin composite before and after treatment with the different whitening products.

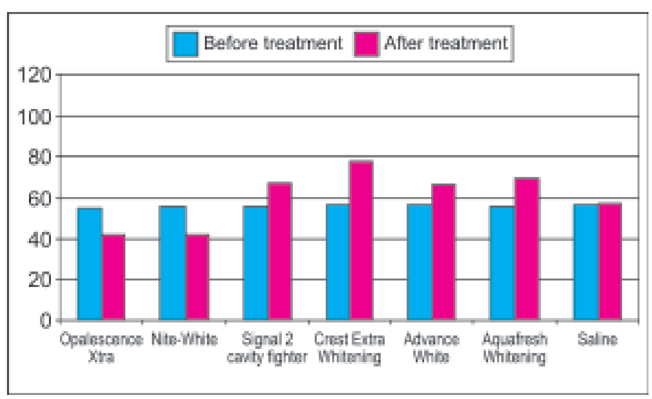

Fig. 3: Mean Vickers hardness values for Fuji II LC before and after treatment with the different whitening products.

The microhardness of the three restorative materials was reduced significantly after treatment with Opalescence Xtra bleaching gel ($P \leq 0.005$). In addition, the microhardness of Fuji II was reduced significantly by Nite-White home bleaching gel (P=0.05).

However, the microhardness of all three restoratives materials was increased significantly after 30 d of brushing with all of the tooth pastes. Esthet-X and Fuji II specimens treated with Crest Extra Whitening tooth paste were significantly harder than the specimens treated with the other tooth pastes ($P \leq 0.001$).

DISCUSSION

The effects of bleaching agents and whitening tooth pastes on the color and microhardness of three restorative materials were different. Peroxide in bleaching gels decomposes into free radicals that attack organic molecules, releasing other radicals. These radicals break down the large pigmented molecules responsible for color stain into smaller less-pigmented molecules. Hence, removing discoloration and brightening the inherent color.[26] On the other hand, whitening tooth pastes help to control stain because of the abrasives incorporated in the products, which remove pellicle in addition to dental stains.[14]

Opalescence Xtra bleaching gel significantly changed the color of Esthet-X resin composite and Fuji II resin-modified glass-ionomer cement. However, the color of Z250 was not affected. The alteration in color of Esthet-X resin composite could be attributed to the oxidation of surface pigments.[27] Differences in color change between different materials may be a result of different resins, filler content, initiation components and different degrees of conversion of resin monomers.[28,29] Though Z250 and Esthet-X are microhybrids with similar filler content (60% by volume), Esthet-X has a smaller average filler particle size and, therefore, a higher resin content. The higher the resin content of a material, the less its resistance to oxidation.[30] In addition, restorative materials containing urethane dimethacrylate, such as Z250 resin composite, show more color stability than those using Bis-GMA.[31] The presence of HEMA in Fuji II resin-modified glass-ionomer cement increases the susceptibility of the material to water sorption and disintegration, hence changing its color.[32]

Softening of restorative materials by strong oxidizing agents, such as the 37% hydrogen peroxide in Opalescence Xtra, has been reported in other studies.[6,7] These studies support the reduction in microhardness of the three restorative materials used in this study. Though Nite-White bleaching gel contains 10% carbamide peroxide (which upon application breaks down into 3% hydrogen peroxide and 7% urea), it caused a significant reduction in microhardness of Fuji II resin-modified glass-ionomer cement. Chemical softening of a restorative material might occur if bleaching products have solubility parameters similar to those of the resin matrix.[33] Reduction in Fuji II microhardness is the result of erosion of the glass-ionomer matrix with wash-off and release of metal cations from the surface, subsequently reducing its microhardness.[34,35]

Increase in surface microhardness of the three restorative materials was observed after treatment with each of the tooth pastes. This increase in surface microhardness might be a consequence of abrasives such as silica, hydrated silica, calcium carbonate and tri-phosphate in the tooth pastes.[14] The abrasives may loosen the stained matrix. However, exact quantitative information on their abrasive action is unclear. Sodium bicarbonate, which is an active ingredient in Crest Extra Whitening and Advance White tooth pastes, was reported also to have a high abrasive action.[16] Incorporation of abrasives in tooth pastes may help to physically remove stain, but since virtually all tooth pastes contain abrasives some benefit may be expected even by regular products. In this study, no significant difference in color or microhardness was found between restorative materials treated with the regular tooth paste (Signal 2) and the other whitening tooth pastes, except for Crest Extra Whitening. The concept of whitening formulations containing specific chemicals, which reduce or inhibit stain independent of physical effect, would appear to be particularly attractive, since reduced staining may be apparent in sites of the dentition where the abrasive effects of tooth paste would be less obvious. It was anticipated that the increase in surface microhardness of the three restorative materials in this study was attributed to the action of the abrasives which produce smooth and, hence, harder surfaces.

Esthet-X and Fuji II specimens showed significantly high color change and increase in microhardness when treated with Crest Extra Whitening tooth paste. These changes may be related to alterations in the structural integrity of the restorative materials, as previously mentioned, and to material interactions with different ingredients from the tooth pastes. The combined abrasive action of hydrated silica and sodium bicarbonate, in addition to the softening effect of citric acid in Crest Extra Whitening, could produce a smooth and hard surface for Esthet-X and expose the surface silica core in Fuji II, thus increasing their surface microhardness and color instability.[36]

The results of this study indicated that bleaching agents and tooth whitening products may affect the color and microhardness of existing restorations, and that this effect is material dependant. Nevertheless, problems with color matching of anterior restorations after bleaching will occur even if the restorations are unaffected. If the restorations match perfectly the color of teeth before bleaching, they may no longer match once the teeth have become lighter and brighter as a result of bleaching. Hence, the restorations may require replacement or resurfacing. Therefore, patients should be advised that existing anterior restorations may not match the natural teeth after bleaching, and that replacement may be required.

This study was carried out in vitro and the results may not be relevant clinically where the interplay of other oral factors has to be considered. Therefore, in situ studies are needed.

CONCLUSIONS

- The color of Z250 resin composite was not affected by the bleaching gels or tooth pastes used. However, the microhardness was significantly reduced by Opalescence Xtra bleaching gel, but increased by all the tooth pastes tested.
- Significant color change and reduction in microhardness of Esthet-X resin composite were observed after treatment with Opalescence Xtra bleaching gel. However, the microhardness of Esthet-X also was significantly increased by all tooth pastes tested in the study.
- Fuji II LC showed significant color change and reduction in microhardness with both bleaching gels, and significant color change and increase in microhardness with all tooth pastes. These findings supported the study hypotheses.
- The results indicated that the effects of bleaching gels and whitening tooth pastes on color and microhardness were restorative material dependent.

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